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(71) Applicant: E.I. DU PONT DE NEMOURS AND COMPANY
[US/US]; 1007 Market Street, Wilmington, DE 19898 (US).

(72) Inventor: ANDERSON, Albert, Gordon; 2410 Saint Francis
Street, Wilmington, DE 19808 (US).

(74) Agent: SIEGELL, Barbara, C.; E.I. du Pont de Nemours and
Company, Legal Patent Records Center, 1007 Market Street,
Wilmington, DE 19898 (US).

(54) Title: PREPARATION OF HYDROXY URETHANES

(57) Abstract

The reactions of cyclic carbonates, especially 1,3-dioxolan-2-ones, with amines, especially primary amines, are catalyzed by the presence of a base whose conjugate acid has a pKa of about 11 or more. The products are hydroxy urethanes, and the process can be used to form cross-linked polymers which contain urethane groups. Such cross-linked polymers are useful in coatings.

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TITLE

PREPARATION OF HYDROXY URETHANES

FIELD OF THE INVENTION

Disclosed is a process for the preparation of hydroxyurethanes from
 5 amines and cyclic carbonates, catalyzed by a strong base whose conjugate acid has
 a pKa of about 11 or more.

TECHNICAL BACKGROUND

Cyclic carbonates, particularly cyclic carbonates containing 5-membered
 rings (1,3-dioxolan-2-one rings), react relatively slowly with amines, particularly
 10 at ambient (about 25°C) temperatures. This slow reactivity has limited the
 usefulness of these types of reactions, for example in coatings which crosslink at
 ambient temperature. Therefore, means of speeding up such reactions are desired.

V. D. Nemirovsky, et al., J. Polym. Sci. C, vol. 16 (1967), p. 1471-1478
 and J. Tabushi, et al., Nippon Kagaku Zasshi, vol. 84 (1963), p. 162-167, report
 15 that carbamate groups catalyze the reaction of certain cyclic carbonates and
 amines. However, the catalysis is slight, about a 30% increase in rates.

SUMMARY OF THE INVENTION

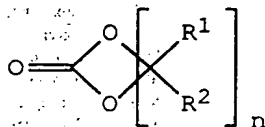
This invention concerns a process for the preparation of hydroxyurethanes,
 comprising, contacting a cyclic carbonate, a primary amine, and a catalytically
 20 effective amount of a base whose conjugate acid has a pKa of about 11 or more.

This invention also concerns a process for the production of hydroxy-
 urethanes by reacting a cyclic carbonate with a primary amine, wherein the
 improvement comprises, using as a catalyst a catalytically effective amount of a
 base whose conjugate acid has a pKa of about 11 or more.

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DETAILS OF THE INVENTION

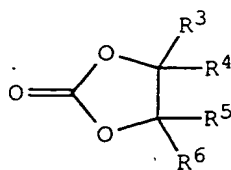
A cyclic carbonate herein has its usual meaning, for instance a compound
 of the formula



(I)

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wherein each R¹ and each R² is independently hydrogen, hydrocarbyl or
 substituted hydrocarbyl and n is 2 or 3. A preferred cyclic carbonate is

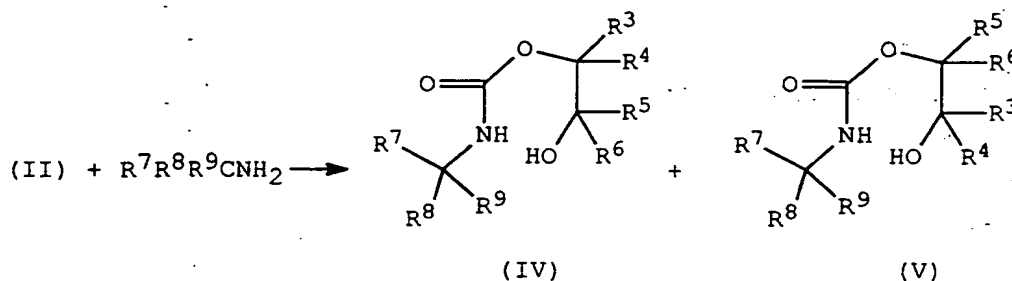


(II)

wherein R^3 , R^4 , R^5 and R^6 are each independently hydrogen, hydrocarbyl or substituted hydrocarbyl. In more preferred cyclic carbonates (individually or collectively) R^3 is Ar^1OCH_2- , $H_2C=C(CH_3)-C(O)-OCH_2-$ or $H_2C=CH-C(O)-OCH_2-$, R^4 is hydrogen, R^5 is hydrogen and/or R^6 is hydrogen, wherein Ar^1 is aryl or substituted aryl. In another preferred form of (II), one of R^3 , R^4 , R^5 or R^6 is attached to a polymer (either directly or through a connecting group), i.e., the cyclic carbonate is a pendant group from a polymer chain.

By a primary amine herein is meant the usual meaning, a compound containing the $-NH_2$ group. It is preferred that this group be bound to an alkyl-type carbon atom, i.e., $R^7R^8R^9CNH_2$ wherein R^7 , R^8 and R^9 are each independently hydrogen, hydrocarbyl or substituted hydrocarbyl. In one preferred amine R^7 , R^8 and R^9 are each independently hydrogen or alkyl, and more preferably R^7 and R^8 are hydrogen and R^9 is alkyl or cycloalkyl.

When the cyclic carbonate reacts with a primary amine, the product is a hydroxy urethane. For example, reaction of (II) with a primary amine may be written as:



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By hydrocarbyl herein is meant a univalent radical containing only carbon and hydrogen. By substituted hydrocarbyl is meant hydrocarbyl substituted with any group that does not interfere with the formation or stability of the cyclic carbonate. Suitable substituent groups include, but are not limited to, halogen, ester, amide, ether and thioether. Substituted aryl is analogous to substituted hydrocarbyl, with the same useful substituents.

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The catalyst herein is a base whose conjugate acid has a pKa of about 11 or more, more preferably about 13 or more. One or more bases whose conjugate acid has a pKa of about 11 or more can be used in the process. The pKa is measured in water. For those bases whose conjugate acid has a pKa of about 14 or more, the basicity can't be measured in water, but the pKa of the conjugate acid will clearly be above 14 in water, because the conjugate acid of the base being measured will be essentially completely formed, along with hydroxyl anion. pKa's, especially for those compounds whose pKa is above about 14, can be measured as described in J. March, "Advanced Organic Chemistry," 3rd Ed., John Wiley & Sons, New York (1985), p. 218-236 and references cited therein, and which is hereby included by reference.

Useful bases are shown in Table 1, along with approximate pKa's (pKa's greater than 14 were measured in solvent systems other than water) taken from literature sources. Preferred bases are t-butoxide, and N,N-bis(trimethylsilyl)-amide (anion), and t-butoxide is especially preferred. It is also preferred that the base be added in the form of an alkali metal or ammonium salt, and more preferred if it is a potassium salt. The alkali metal or ammonium cations are the counterions of the base anion.

TABLE 1

<u>Base</u>	<u>pKa</u>
malononitrile anion	11.0
alkyl acetoacetate anion	11.0
methylene disulfone anions	12.5
trifluoroethoxide	12.4
diethyl malonate anion	13.0
N-methyl ethylcarbamate anion	14.5
methoxide	15.2
hydroxide	15.7
ethoxide	16.5
t-butoxide	17.0
N-alkylamide anion	17.0
anions of benzyl alcohols	16-18
anions of alkyl or aryl ketones	19-20
diphenylamine anion	21.0
triphenylmethoxide	24.0
N,N-bis(trimethylsilyl)amide anion	28-29

The concentration of base present is that needed to be an effective catalyst.

By an effective catalytic amount is meant that the rate of reaction of the cyclic carbonate with the amine is at least twice the rate when the base (catalyst) is absent. The rate of reaction is measured by a reaction in a ^1H Nuclear Magnetic Resonance (NMR) tube under appropriate conditions (see procedure in the Examples). The time to approximately (but the exact same amount of reaction for each sample) half reaction is measured, and to be considered an effective catalyst (base) concentration, the time with the catalyst should be 50% or less (based on the time without catalyst), preferably 25% or less, of the time without catalyst.

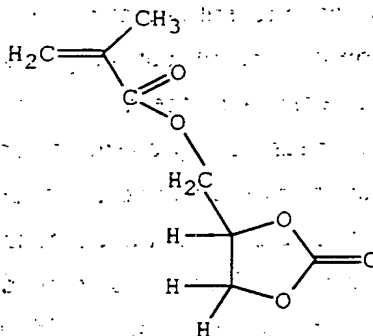
A preferred amount of catalyst, based on the moles of the cyclic carbonate present is about 1 mole percent to about 10 mole percent, more preferably about 1.5 mole percent to about 5 mole percent.

Temperature of the process is not critical, a preferred temperature range being about -20°C to about 120°C , more preferably about 0°C to about 60°C , and especially preferably about 10°C to about 40°C . Ratios of reactants are not critical, but in order to most efficiently utilize the ingredients a molar ratio of about 1:1 for the cyclic carbonate and primary amine groups is preferred.

The reaction of cyclic carbonates with primary amines is a known reaction, see for instance British Patent 689,705, U.S. Patents 3,072,613 and 4,882,391, and French Patent 1,096,204, all of which are hereby included by reference. In general all that is necessary for the reaction to occur is to bring the reactants into contact, as in solution, or if one or both of the primary amine and carbonate are liquids, without solvent for a period of time sufficient to carry out the reaction.

Polymers that contain cyclic carbonate groups are especially useful since they may be crosslinked by multifunctional compounds that can react with the cyclic carbonate group. Multifunctional amines are particularly desirable in this respect, since upon reaction with the cyclic carbonate urethane groups are formed. Urethane groups are desirable in polymers for certain uses; for example, in coatings urethane groups tend to impart certain improved properties such as gloss, impact resistance, adhesion and toughness.

The cyclic carbonate groups can be introduced into polymers by being part of polymerizable monomers. For instance glycidyl (meth)acrylate may be reacted with CO_2 to form the compound



(III)

which may be free radically copolymerized with other (meth)acrylates to form a copolymer which may be crosslinked with a di- (or higher) functional primary amine or a primary amine containing polymer. Such a cyclic carbonate containing polymer preferably contains an average of 2 or more cyclic carbonate groups per polymer molecule. Conversely, a polymer containing primary amine groups may be crosslinked by a compound containing two or more cyclic carbonate groups or a polymer containing cyclic carbonate groups. In both instances, the crosslinks contain desirable urethane groups.

In the catalyzed process described herein the catalyst may be premixed with either the polymer or crosslinking compound, and then the polymer and crosslinking compound (and the catalyst) mixed with each other, and the polymer will eventually crosslink. If meant for a coating, the mixture of the polymer crosslinking agent and catalyst may be applied in a normal manner (e.g., spraying or brushing) and upon standing at ambient conditions the polymeric coating will crosslink. Other ingredients normally present in such coatings can also be present, such as pigments, dyes, antioxidants, reflective agents, dispersants, etc.

Coatings which are crosslinked by the catalyzed process described herein are especially useful for transportation vehicles such as airplanes, automobiles, trucks and railroad cars. They are especially suitable for refinish operations, i.e., repainting of a surface after the coated object has been in service for some time period. The coatings may be applied without the need for baking, as is often done when the transportation vehicle is first manufactured. Since urethane linkages are produced without the uncrosslinked coating containing isocyanate groups, (potential) toxicity problems caused by isocyanate containing compounds are avoided.

EXAMPLES 1-8 AND COMPARATIVE EXAMPLE A

All of these Examples and Comparative Example were done by the same general procedure.

A solution, "A", of 0.2654 g of 4-[(pivaloyloxy)methyl]-1,3-dioxolan-2-one and 0.044 g of durene (as an NMR internal standard) was prepared in 0.275 ml of THF-d₈ (tetrahydrofuran). A solution, "B", was prepared from 86.5 µl of N-butylamine (8.75x10⁻⁴ mole) and 25 µl of THF-d₈. Then 360 µl of solution "A" (8.75x10⁻⁴ mole cyclic carbonate) and all of solution "B" were carefully layered into an NMR tube. The 25 µl of THF-d₈ was added to the tube, followed by a solution of 26.3 µl of 1.0 M potassium tert-butoxide in THF (3 mole % KO-t-Bu) was then added to the NMR tube and the whole mixed just prior to taking the NMR spectrum.

NMR spectra were taken on a GE Omega® 300 spectrometer operating at 300.275 MHz, relative to a tetramethylsilane internal standard and are given in ppm. The integrated NMR values observed and used for computing the concentration of starting amine (which was equal to starting cyclic carbonate), a, and the resulting urethane, b, were located at δ=2.58 ppm for the N-methylene group of the N-butylamine, and δ=3.03 ppm for the N-methylene group of the resulting urethane. The relative decrease in the concentration of the amine at a given time was calculated as a/(a+b).

Table 2 shows the decrease in butylamine concentration with time relative to the total amine plus urethane concentration when the reaction was catalyzed by 3 mol% KO-t-Bu. For comparison, the same reaction run without addition of catalyst (Comparative Example A) is also given. The time given is taken from the time of initial mixing of the components.

TABLE 2

Comp. Ex. A No Catalyst		Ex. 6 3 mole % KO-t-Bu	
Rel. Fraction Amine Remaining	Time (min)	Rel. Fraction Amine Remaining	Time (min)
0.96	6	0.36	1
0.80	39	0.18	9
0.65	72	0.13	17
0.52	105	0.11	25
0.46	138	0.088	33
0.38	171	0.078	41
0.32	204	0.066	49
0.28	237	0.056	62
0.27	270	0.052	75
0.23	333	0.045	88
0.20	396	0.041	101

0.17	459	0.038	114
0.16	522	0.036	126
0.14	585	0.036	139
0.13	648	0.030	152
0.11	771	0.030	165
0.098	894	0.028	188
0.086	1017	0.026	211

All of the other Examples were run in the same manner except for varying the type and/or amount of catalyst present. Results for all of the Examples are shown in Table 3.

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TABLE 3

Example	Catalyst ^a	Time (min) ^b					
		0	15	30	45	60	120
A	none	1.00	0.94	0.86	0.77	0.69	0.49
1	1% KO-t-Bu	1.00	0.94	0.86	0.77	0.69	0.49
2	10% aceto	1.00	0.74	0.66	0.56	0.52	0.38
3	1.5% KO-5-Bu	1.00	0.38	0.28	0.24	0.20	0.14
4	10% silyl	1.00	0.30	0.17	0.12	0.08	0.04
5	2% KO-t-Bu	1.00	0.20	0.13	0.09	0.07	0.04
6	3% KO-t-Bu	1.00	0.14	0.09	0.07	0.06	0.04
7	5% KO-t-Bu	1.00	0.11	0.05	0.03	0.02	0.01
8	10% KO-t-Bu	1.00	0.05	0.02	0.01	0.00	0.00

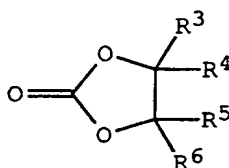
^aKO-t-Bu is potassium t-butoxide, aceto is tetramethylammonium ethyl 2-acetoacetate, and silyl is potassium (bis)trimethylsilylamide. Percents are mole percent based on cyclic carbonate

^bNumbers given are relative (to time zero) amounts of amine remaining at the given time

CLAIMS

What is claimed is:

1. A process for the preparation of hydroxyurethanes, comprising,
 contacting a cyclic carbonate, a primary amine, and a catalytically effective
 amount of a base whose conjugate acid has a pKa of about 11 or more.
2. A process for the production of hydroxyurethanes by reacting a cyclic
 carbonate with a primary amine, wherein the improvement comprises, using as a
 catalyst a catalytically effective amount of a base whose conjugate acid has a pKa
 of about 11 or more.
3. The process as recited in Claim 1 or Claim 2 wherein said cyclic
 carbonate is



(II)

- wherein R³, R⁴, R⁵ and R⁶ are each independently hydrogen, hydrocarbyl or
 substituted hydrocarbyl.
4. The process as recited in Claim 1 or 2 wherein said cyclic carbonate is
 part of a polymer.
5. The process of Claim 3 wherein R³ is selected from the group
 consisting of Ar¹OCH₂-, H₂C=C(CH₃)-C(O)-OCH₂- and H₂C=CH-C(O)-OCH₂-,
 R⁴ is hydrogen, R⁵ is hydrogen and/or R⁶ is hydrogen, wherein Ar¹ is aryl or
 substituted aryl.
6. The process as recited in Claim 4 wherein said polymer is crosslinked.
7. The process as recited in Claim 6 wherein said polymer is part of a
 coating.
8. The process as recited in Claim 1 or Claim 2 wherein a counterion to
 said base is an alkali metal cation or an ammonium ion.
9. The process as recited in Claim 1 or Claim 2 wherein said base is
 t-butoxide.
10. The process as recited in Claim 9 wherein a counterion for said
 t-butoxide is potassium.
11. The process as recited in Claim 1 or 2 carried out at a temperature of
 about -20°C to about 120°C.

12. The process as recited in Claim 11 carried out at a temperature of about 0°C to about 60°C.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/09202

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C07C269/04 C08F8/32

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C07C C08F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	THOMAS BÜRCEL ETAL.: "Epoxy Resins with Cyclic Carbonate Structures" POLYMER BULLETIN, vol. 30, no. 1, January 1993, pages 61-68, XP000343828 see the whole document	1-12
A	GB 689 705 A (SOCIÉTÉ ANONYME DE SAINT-GOBAIN, CHAUNY & CIREY) 26 June 1955 cited in the application see claims; examples	1-3,5, 8-12
A	US 3 072 613 A (JOHN M. WHELAN ET AL.) 8 January 1963 cited in the application see claims	4,6-12
-/-		

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

14 September 1998

Date of mailing of the international search report

21/09/1998

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NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/09202

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 4 882 391 A (GERHARD BRINDÖPKE ET AL.) 21 November 1989 cited in the application see claims</p>	4,6-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/09202

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 689705 A		NONE	
US 3072613 A	08-01-1963	NONE	
US 4882391 A	21-11-1989	DE 3644373 A CA 1334237 A DE 3787459 D EP 0274721 A ES 2059353 T JP 63168405 A	07-07-1988 31-01-1995 21-10-1993 20-07-1988 16-11-1994 12-07-1988